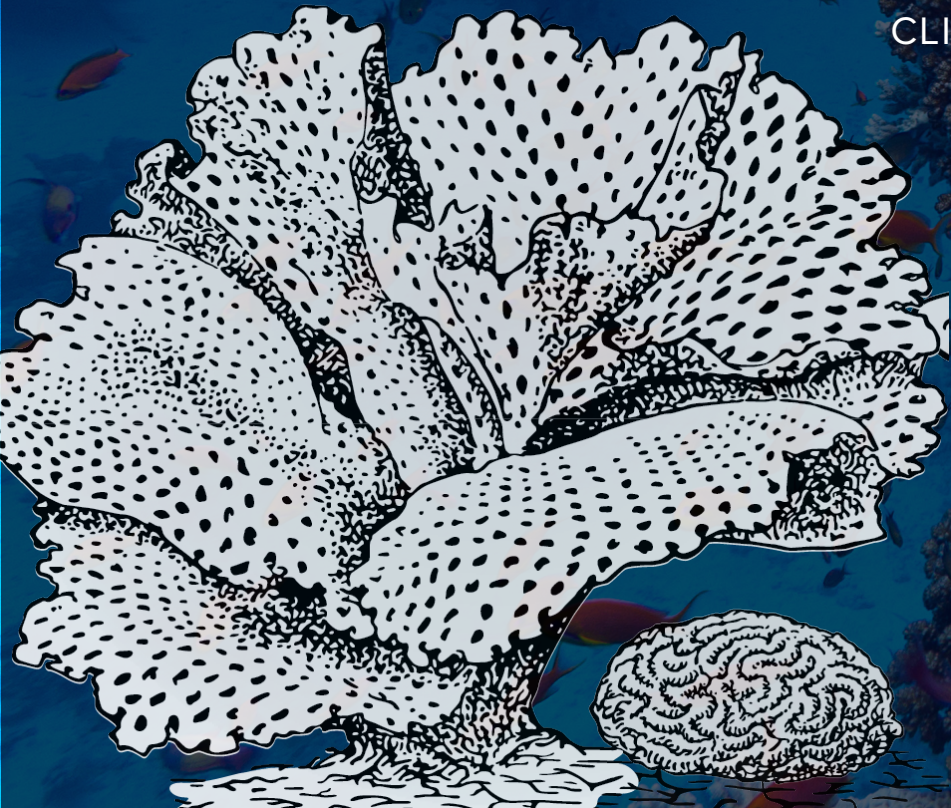


# BIOMIMICRY CARBON SOLUTIONS REPORT

NATURE INSPIRED  
SOLUTIONS TO COMBAT  
CLIMATE CHANGE



BIOMIMICRY 3.8

# Biomimicry

*Biomimicry is innovation inspired by nature. It is unique among nature-inspired approaches to design in that it emulates functional strategies from the natural world developed as a result of 3.8 billion years of evolution. Using nature as a model produces smart design and sustainable innovation that creates conditions conducive to life.*



## BIOMIMICRY 3.8

At Biomimicry 3.8, we help change-makers transform the world by emulating nature's strategies and core principles. With **Biomimicry Solution Reports**, we outline actionable, high-impact opportunities to realize biomimetic gains and start affecting positive change in the most pressing challenges for a sustainable world.

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### Contributors:

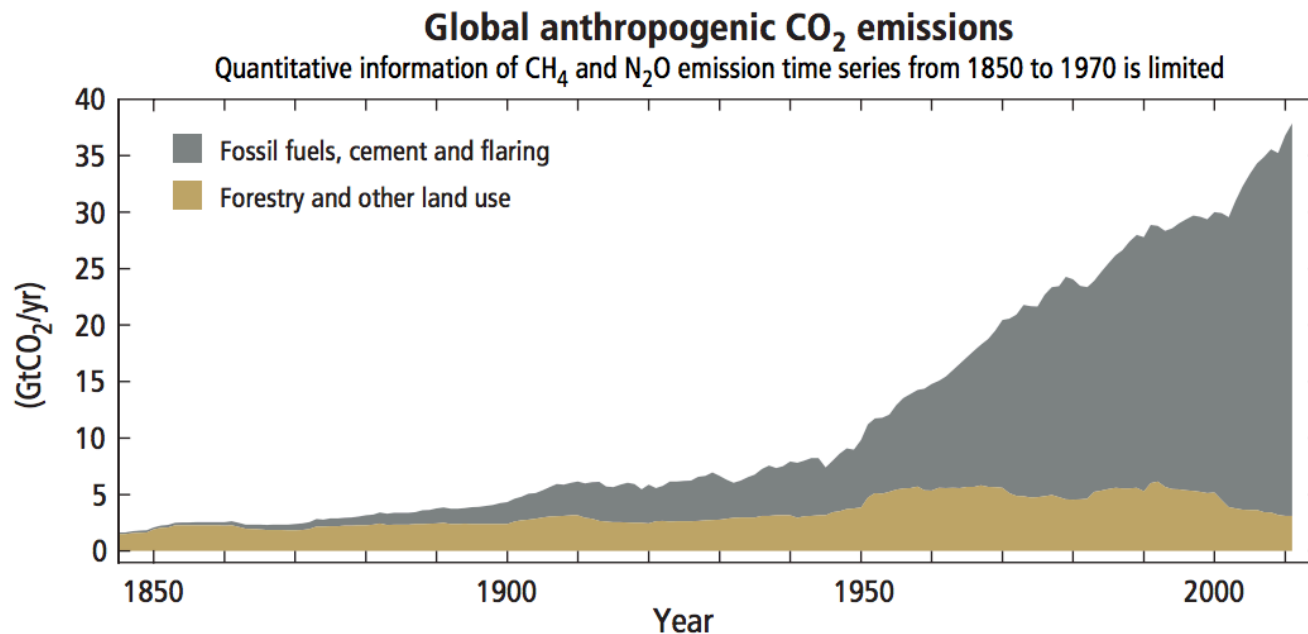
Erin Rovalo, Senior Principal  
Jamie Dwyer, Principal  
Mark Dorfman, Principal

# THE CARBON CHALLENGE

We know that carbon emissions are a major contributor to global climate change trends and that the challenge of mitigating and even reversing this trend is highly complex. We also know that, like so many other challenges we face, managing carbon is a challenge

faced by the natural world and solved for in its own adaptive strategies that have evolved over 3.8 billion years of living with carbon. This report takes a hopeful look at existing inspiring solutions drawn from nature's genius that can help us meet the carbon challenge

— reversing climate change by eliminating emissions and drawing carbon down out of the atmosphere and into products and process — and promote a world that creates conditions conducive to life for all.



*“Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.”*

Source: IPCC Fifth Assessment 2014

# HOW DOES NATURE MANAGE CARBON?

The natural carbon cycle is a constant operating condition of the Earth and the natural world, including organisms and ecosystems, and has evolved strategies to manage and even take advantage of the presence of carbon.

Looking to the natural world for carbon solutions offers new insights in how we can:

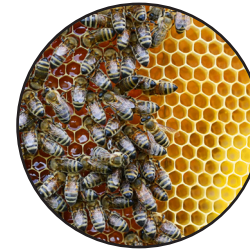
1. Minimize the carbon footprint of energy and materials production
2. Sequester carbon where emissions are present
3. Use carbon as a feedstock to produce innovative materials and commodities

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## CHAMPION ADAPTERS FEATURED IN THIS REPORT INCLUDE:



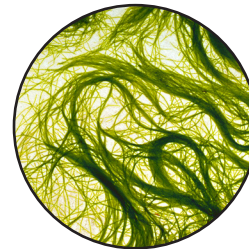
SEA KELP



COLONY  
INSECTS



PLANT FIBERS



PLANTS  
& ALGAE



FOREST  
ECOSYSTEMS



SCHOOLS  
OF FISH



CORAL  
REEFS



PRAIRIE  
ECOSYSTEMS

# Biomimicry Solutions

*In this Biomimicry Solutions Report, we outline nine innovations inspired by these champion adapters that can help slow and reverse climate change through inventive management of carbon.*

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01 BIOWAVE

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02 VAWT WIND  
FARM DESIGN

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03 SWARM LOGIC  
TECHNOLOGY

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04 AIRCARBON

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05 CARBON MIX

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06 MULTI-STRATA  
AGROFORESTRY

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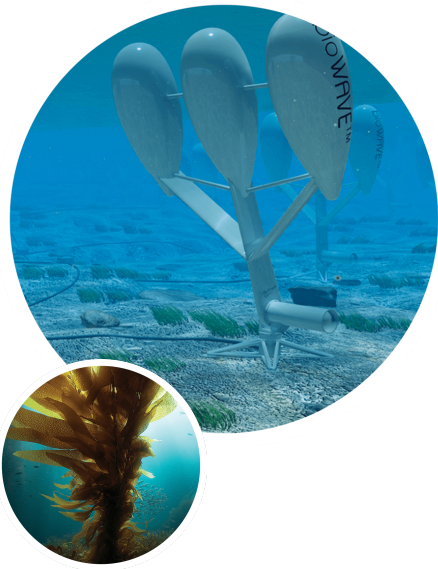
07 ECOLOGICAL  
PERFORMANCE  
STANDARDS

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08 PERENNIAL  
CROPS

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09 ZELFO



#### INSPIRED BY

### Kelp

Kelp grow into kelp forests in shallow ocean waters. Kelp often resemble a vine-like plant with a long, thin stem-like structure up to 30 meters long, anchored into the sea floor by a root-like holdfast. The fronds of kelp are kept at or near the sea surface via gas-filled floats. Instead of being rigid, kelp sway with the motion of the ocean waves.

#### FUNCTIONS

manage flow

manage buoyancy

#### FOR MORE BIOLOGY

<https://goo.gl/vDkuHB>

#### BIOMIMICRY SOLUTION

product



#### ORGANIZATION



BPS is a renewable energy company based in Sydney, Australia. Established in 2006, BPS is following a strategic path towards offering advanced renewable energy products to the global market. Their products are designed using nature-inspired principles, combined with rigorous best-practice engineering, and are intended to provide cost-effective clean energy supply in a wide range of conditions and locations.

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Excerpted from:  
bps.energy

## bioWAVE

Stage of Development **pilot project**

The bioWAVE is a renewable energy technology that extracts energy from ocean waves, allowing direct conversion to certifiable grid-quality electricity. The bioWAVE is a submerged structure that absorbs energy from waves and converts it to electricity that is delivered to onshore consumers by a subsea cables. Each bioWAVE can produce up to 250kW of steady electrical power, roughly equivalent to about 200 houses. Electricity supplied from bioWAVE is expected to be more consistent than supply from wind or solar power, and could be the considered near-baseload in many locations.



#### Innovation Advantage

Modular design allows for easy installation and low-cost maintenance; Safety mode protects equipment during storms; Uses the standardized power-conversion O-Drive module



#### Sustainability Advantage

Harvests renewable energy; Efficient onboard conversion to high-voltage AC power; Buffers wave action on coastline

#### OPPORTUNITY

pilot partnership

BioPower is actively looking for pilot projects in order to improve the technical and commercial performance of all their products. Their ultimate aim is to deliver its products to micro-grid, off-grid, and island customers and to utility-scale projects connected to distribution grids.

Potential Applications | **industrial** **infrastructure**



## INSPIRED BY Mackerel

As fish swim, they shed tiny vortices. In large schools of fish, individuals transfer energy to each other with these vortices, lowering the energetic costs compared to each fish swimming independently.

## FUNCTIONS

move through liquids

## FOR MORE BIOLOGY

<https://goo.gl/4xADNn>

BIOMIMICRY SOLUTION

best practice



ORGANIZATION

## VAWT Wind Farm Design

Stage of Development **pilot project**

Vertical Axis Wind Turbines (VAWT) have multiple blades that are always perpendicular to the ground and parallel to each other, whereas "conventional" Horizontal Axis Wind Turbines (HAWT) have blades radiating from a central point and are alternately horizontal or perpendicular to the ground. VAWTs have numerous performance and environmental advantages over HAWTs particularly when placed together in wind "farms" -- a design inspired by the movement of schools of fish.



### Innovation Advantage

VAWT wind farms can produce 32% more power per square area. They allow for smaller structures (30 ft tall vs 300 ft) and lower materials costs since they don't require carbon fibers or other high tech materials for support.



### Sustainability Advantage

VAWT wind turbines are easier for birds and bats to detect, so they are safer for birds and bats. Their radar signature on man-made radars is minimal.

## OPPORTUNITY

pilot partnership

Interested parties should contact Dr. Dabiri for how to take advantage of VAWT best practices. The technology is scalable, so it is applicable to private residences, communities, industrial settings, and municipalities.

Potential Applications | **commercial** **residential** **municipal**

## DABIRI LAB Stanford University

Stanford University's Dabiri Lab specializes in improving energy efficiency through application of nature's engineering principles. Along with improved wind power generation inspired by schools of fish, the Dabiri lab has also created more efficient submarine propulsion systems inspired by jellyfish.

## PRIMARY CONTACT

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Excerpted from:  
[dabirilab.com](http://dabirilab.com)



#### INSPIRED BY

### Bees, ants, wasps

Colony insects such as bees, ants, and wasps exhibit swarm behavior. Individuals are not subjected to centralized control, yet the whole colony can act in a coordinated manner. Swarm behavior is behind complex decisions and activities such as bees choosing new colonies and ants construct their mounds.

#### FUNCTIONS

process information

#### FOR MORE BIOLOGY

<https://goo.gl/T4CsK1>

BIOMIMICRY SOLUTION

service

 BIOMIMICRY 3.8

ORGANIZATION

## Swarm Logic Technology

Stage of Development **commercialized product**

Using Swarm Logic®, clients get smart energy consumption. Encycle's energy service depends on its Swarm Logic technology that creates a holistic demand management system. Using swarm intelligence biomimicry, the technology enables customers to shave off expensive and environmentally damaging peak demand, participate in utility demand response schemes, and realize energy savings through intelligently smoothing out energy demand. Encycle's enabling technologies (the Swarm Controller™, SwarmStat™, and Swarm Service™) allow clients to implement Swarm Logic with their current thermostat technology.



#### Innovation Advantage

Overall lower energy costs lead to unprecedented ROI; Ease of installation means fast results; Technology allows clients to use their current smart thermostats within the system



#### Sustainability Advantage

Swarm Logic can reduce peak demand energy charges as much as 25%; Energy consumption can be cut by 30% thus reducing carbon emissions

#### OPPORTUNITY

**purchase through rep**

Swarm Logic® Technology is available for purchase under the Energy as a Service by Encycle™ program. The process begins with a site evaluation that results in a report and a proposal from Encycle. The system is then available to purchase directly from Encycle or from select partners.

Potential Applications |

commercial

retail

schools

**light industrial**

office



Encycle has one focused mission: to leverage the amazing power of biomimicry to make rooftop HVAC systems much smarter. The company offers peak energy demand reduction and intelligent energy management solutions. Its patented Swarm Energy Management system uses a software algorithm and wirelessly communicating control units to mimic the swarm intelligence of bees.

#### PRIMARY CONTACT

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Excerpted from:  
[encycle.com](http://encycle.com)



**INSPIRED BY****Plants and Algae**

Photoautotrophs are species that are able to produce their own food through photosynthesis. As such, plants, algae, cyanobacteria and some microbes use carbon dioxide as a feedstock to make energy, food and products. Carbon fixation is part of the photosynthesis process. Sunlight, carbon dioxide, and water are converted to oxygen and organic materials.

**FUNCTIONS**

absorb carbon

store carbon

**AirCarbon**

Stage of Development

commercialized commodity

AirCarbon™ is a high-performance plastic material made with captured methane-based carbon emissions that would otherwise be released to the atmosphere. Newlight uses an award-winning greenhouse gas-to-plastic bioconversion technology inspired by plants and algae to produce plastics from air and methane-containing greenhouse gas emissions from a farm. AirCarbon is made using a biocatalyst that allows AirCarbon to out-compete oil-based plastics, such as polypropylene and polyethylene, on price. AirCarbon transforms the products we use every day into products that reverse the flow of carbon.

**Innovation Advantage**

AirCarbon is able to meet the performance requirements of a wide range of applications, including applications currently using fossil fuel-based polypropylene, polyethylene, ABS, polystyrene, and TPU.

**Sustainability Advantage**

AirCarbon is made from carbon capture, not fossil fuels; 60% carbon and hydrogen from captured methane emissions by weight; Carbon-negative as verified by 3rd party, including all energy, materials, transportation, product use, and disposal

**OPPORTUNITY**

purchase through rep

license the technology

AirCarbon in can be used in extrusion, blown film, cast film, thermoforming, fiber spinning, and injection molding applications. AirCarbon is available for purchase through Newlight Technologies. Companies can also license the AirCarbon technology.

Potential Applications |

products

packaging



Newlight Technologies has a mission to replace oil-based plastics with greenhouse gas-based plastics on a global scale, moving oil out of the world's products, reducing material production costs, and reducing the amount of carbon in the air on a market-driven basis. Newlight has developed, patented, and commercialized the world's first commercially-scaled carbon capture technology able to produce high-performance thermoplastics from air and methane emissions.

**PRIMARY CONTACT**

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CEO

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Costa Mesa, CA USA

Excerpted from:  
[newlight.com](http://newlight.com)

**FOR MORE BIOLOGY**

<https://goo.gl/5FhZY0>



#### INSPIRED BY

### Common Stony Coral

In daylight, carbon dioxide generated from cellular metabolism in the coral polyp diffuses into a closed space directly above existing coral skeleton. With the aid of the carbonic anhydrase enzyme, CO<sub>2</sub> is transformed to bicarbonate and carbonate ions. Another enzyme facilitates the import of a calcium ions and formation of solid calcium carbonate.

#### FUNCTIONS

store carbon

#### FOR MORE BIOLOGY

<https://goo.gl/gVdsi7>

BIOMIMICRY SOLUTION

technology



ORGANIZATION

## CarbonMix

Stage of Development commercialized commodity

Blue Planet's technology uses CO<sub>2</sub> as a raw material for making carbonate rocks. The carbonate rocks produced are used in place of natural limestone rock mined from quarries, which is the principal component of concrete. CO<sub>2</sub> from flue gas is converted to carbonate (or CO<sub>3</sub>) by contacting CO<sub>2</sub> containing gas with a water-based capture solutions. Blue Planet's carbonate rocks are used as aggregates in concrete, in highly reflective roofing tiles, and as an alternative to titanium dioxide white pigment.

#### Innovation Advantage

Aggregate in sizes ranging from sand grain to gravel. Blue Planet CaCO<sub>3</sub> powder, is 100x less expensive than TiO<sub>2</sub>, also exhibits a higher solar reflectance than TiO<sub>2</sub>. (96%). Can be used in food, beverage and cosmetics as a TiO<sub>2</sub> replacement or filler.

#### Sustainability Advantage

Avoids the need to mine limestone. Removes CO<sub>2</sub> from flue gas. Each rock particle is coated with BP's synthetic limestone, forming a carbon-sequestering coating that is 44% by mass CO<sub>2</sub>. Allows for CO<sub>2</sub> sequestration without first purifying CO<sub>2</sub>.

#### OPPORTUNITY

pilot partnership

Contact Blue Planet for information on using Blue Planet's process to reduce atmospheric CO<sub>2</sub> emissions or for purchasing the company's products generated from CO<sub>2</sub> including aggregates, sack concrete, roofing granules, cool pigments, and purified CO<sub>2</sub>.

Potential Applications | all building types building material roofing material



Blue Planet's mission is to develop and commercialize a scalable solution for CO<sub>2</sub> mitigation that is both economically and technically sustainable. Blue Planet provides CO<sub>2</sub> capture and sequestration, criteria pollutant removal, and water management services to emitters in the coal, gas, cement and refinery industries.

#### PRIMARY CONTACT

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Excerpted from:  
[blueplanet-ltd.com](http://blueplanet-ltd.com)



#### INSPIRED BY

### Forest Structure

Forests often have an emergent layer (trees that poke up out of the canopy), canopy, understory, and forest floor layers. The sunlight, wind, water and temperatures vary throughout the layers. With stratification and diversity of different conditions, a mature forest can support many species, and the species contribute to forest function and health.

#### FUNCTIONS

provide ecosystem services

#### FOR MORE BIOLOGY

<https://goo.gl/DRVHMd>

#### BIOMIMICRY SOLUTION

best practice



## Multistrata agroforestry

Stage of Development replicable strategy

Agroforestry is forestry combined with agriculture and even livestock. Multistrata agroforestry is sometimes also called agroecology, holistic management, or forest gardening, to name a few. In multistrata agroforestry, the trees, crops, and even livestock overlap but occupy different vertical layers of the system. The method focuses on the process of working with the natural succession of the land, instead of depending on the ability to add fertilizer and water to the system. Inputs of organic matter from pruning stay in the system, creating a more fertile soil over time.



#### Innovation Advantage

Multistrata agroforestry is flexible and can be integrated into existing agricultural systems, no matter where and with any starting conditions. This regenerative system is highly productive by working with the natural processes.



#### Sustainability Advantage

Besides carbon uptake and storage, multistrata agroforestry practices can increase the land's ability to provide ecosystem services such as preventing erosion, recharging groundwater, healing soils, supporting biodiversity, and preventing floods.

#### OPPORTUNITY

acquire the knowledge

As a land management and agricultural strategy, multistrata agroforestry can be applied to any land. It is a best practice with techniques and principles that take time to implement. This opportunity features one prominent teacher/consultant in the field.

Potential Applications | farms campus gardens ranches city planning

#### ORGANIZATION



Ernst Götsch and the staff at Sintropia explore best practices in Multistrata Agroforestry techniques, as well as Permaculture, Regenerative Agriculture and Agroecology on his land, Syntropia, in Brazil. Götsch has been working land for over 65 years and has passed on his methods to many apprentices who have become prominent in the field. Ernst Götsch's company, Agenda Gotsch, offers hands-on courses as well as a consulting model.

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Excerpted from:  
[agendagotsch.com](http://agendagotsch.com)



BIOMIMICRY SOLUTION

best practice



ORGANIZATION

## Ecological Performance Standards

Stage of Development **pilot project**

Ecological Performance Standards (EPS) are a set of place-based metrics that push built environment projects to become more sustainable. Metrics from a healthy habitat become the project goals and from there, the Biomimicry 3.8 team provides an understanding of what environmental characteristics feed into the metrics so the design team can work to increase the project metrics. Environmental Performance Standards aim to create projects that are functionally indistinguishable from the healthy wildlands next door.

### INSPIRED BY

## Healthy Ecosystems

Groups of organisms form populations. Geographically overlapping populations of different species form communities. The activities and interactions of all the individuals create a cumulative positive effect. Healthy ecosystems store carbon, moderate extreme weather, and treat wastewater.

### Innovation Advantage

Biomimicry 3.8 works with EcoMetrix Solution Group to expedite and streamline the metric gathering process with a digital tool. The tool will also allow the design team to compare ecological performance scenarios.

### Sustainability Advantage

Increased ecosystem service performance can add value to the land and reduce environmental risks. Ecological Performance Standards can also initiate sustainability conversations with neighbors and communities.

### OPPORTUNITY

**pilot partnership**

Ecological Performance Standards are appropriate for projects campus size or larger. Successful projects with Interface provide an initial case study. Biomimicry 3.8 is looking for partners to pilot Ecological Performance Standards.

Potential Applications | **master plan** **campus** **city planning**

### FUNCTIONS

**provide ecosystem services**

### FOR MORE BIOLOGY

<https://goo.gl/jKAZxG>



## BIOMIMICRY 3.8

Biomimicry 3.8 uses the practice of biomimicry to help innovators find inspired design solutions, trains professionals to be the next generation of biomimics, and shares the amazing ways that nature's wisdom solves human problems with people around the world. The Biomimicry 3.8 consulting staff of biologists, chemists, business leaders, and designers work with client teams to incorporate nature's time-tested strategies into products, organizations, and services.

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Excerpted from:  
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BIOMIMICRY SOLUTION

product



ORGANIZATION

## Perennial Crops / Kernza wheat

Stage of Development **commercialized commodity**

Natural ecosystems feature perennials in mutually beneficial relationships known as perennial polycultures powered by sunlight (as opposed to ancient sunlight in the form of fossil fuels). The Land Institute (TLI) is breeding new perennial grain and seed crops adapted to ecologically intensified polycultures. Its goal is to develop an agricultural system that can produce ample food and reduce impacts from the disruptions and dependencies of industrial agriculture. It breeds perennial crops, focusing on domesticating wild perennial species that are good crop candidates, and perennializing existing annual crops.

### INSPIRED BY

#### Prairie grassland

Natural ecosystems feature perennials in mutually beneficial relationships. Those systems are self-sustaining, powered by sunlight, and maintain multiple important processes like pest control, fertility and nutrient cycling, erosion control, drought resistance and water management, and carbon sequestration. These systems produce ample food and biomass.

#### Innovation Advantage

Perennial plants do not have to be reseeded or replanted every year, so they do not require annual plowing or herbicide applications to establish.

#### Sustainability Advantage

Perennial crops are robust; they protect soil from erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, and water infiltration, and can contribute to climate change adaptation and mitigation.

### OPPORTUNITY

**purchase through rep**

At least one perennial (Kernza® wheat) developed by The Land Institute is ready for planting. The wheat can be used in baking, milling, or brewing. Browse through TLI's other Perennial Crops on the web page for specifics about the status of each type of perennial crop. The Land Institute also works directly with organizations interested in growing perennials in polycultures.

Potential Applications | **agriculture** **food production** **large scale agriculture**



Founded as a nonprofit organization in 1976, The Land Institute is committed to researching and developing food production methods that sustain the land and soil, a precious resource in an increasingly precarious state around the globe. At The Land Institute, we believe we must grow food in partnership with nature by planting perennial grains in mixtures that can help build and protect soil.

### PRIMARY CONTACT

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Excerpted from:  
landinstitute.org

### FUNCTIONS

**provide ecosystem services**

### FOR MORE BIOLOGY

<https://goo.gl/QNgU5h>



BIOMIMICRY SOLUTION

material



ORGANIZATION

## Zelfo

Stage of Development

commercialized commodity

Zelfo® is a high-performance bio-based material. Patented fiber technology developed by Zelfo Technology transforms 100% renewable or recycled cellulose fibers and water into self-binding Zelfo material. Zelfo is an economic, adaptable and sustainable alternative to wood, plastics, and other materials for 2D and 3D applications.



Zelfo specializes in producing highly fibrillated macro, micro, and nano-cellulose fibers, either as separate entities or in controlled mixtures. Zelfo Technology's experience in these fields extends to sources from pre-processed and non-processed ligno-cellulosic fibers. Zelfo Technology specializes in IP co-development and IP licensing for 3rd Party product development and improvement.

### INSPIRED BY

## Plant Cellulose

Cellulose is one of the major components of natural fibers. Cellulose microfibrils form long chains that provide stiffness and strength to the cell walls of green plants. As a material, cellulose is an inspiration for how nature self-assembles building materials and as well as a potential feedstock. Cellulose is one of the world's most abundant natural materials.



### Innovation Advantage

Zelfo Technologies has a testing center and they offer full fiber testing services to establish material suitability for clients. The Zelfo process can use multiple source materials such as from agricultural, industrial, and post-consumer sources.



### Sustainability Advantage

Engineered natural fibers can up-cycle fiber-based waste. Recyclable and biodegradable. Energy and water-efficient processing method. Low-carbon footprint for end-of-life disposal. Can contribute to LEED or BREEAM in multiple categories

### OPPORTUNITY

co-develop IP

acquire IP

Zelfo Technology specializes in IP co-development and IP licensing for 3rd Party product development and improvement. The company has enhanced the basic processes described in the various patents we have in place and, as a result, new varieties of materials and composites are constantly emerging. The company is now working with partners to industrialize its processes and to bring the resulting products to the market on a global scale.

Potential Applications |

building material

product design

packaging

automotive

### PRIMARY CONTACT

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Excerpted from:  
zelfo-technology.com

### FUNCTIONS

physically assemble structure

### FOR MORE BIOLOGY

<https://goo.gl/vHR5Kg>

# WHAT'S NEXT

In order for climate change to be reversed and to protect the biodiversity of the planet, we all have a role to play in reducing, sequestering, and drawing down carbon from the atmosphere. Biomimicry can be a rich source of innovative ideas for meeting this difficult challenge. Whatever your opportunity to affect climate change may be, don't forget to ask "How would nature do that?"

## Recommended next steps

- Reach out to key contacts listed in this report for the biomimicry solutions that may be a good fit for your project or company
- Discuss biomimicry's role in your carbon strategy: Set up an advisory meeting with Biomimicry 3.8 by writing to [info@biomimicry.net](mailto:info@biomimicry.net)
- Participate in the [Biomimicry Institute's Global Design Challenge 2018](#) and create a nature-inspired innovation of your own that combats climate change
- Review [Project Drawdown](#) for more existing solutions to reverse global warming
- Go outside and get inspired by nature's genius



## BIOMIMICRY 3.8

To learn how Biomimicry 3.8 can inform your next innovation, visit [Biomimicry.net](http://Biomimicry.net).



To explore more biomimicry resources and tips from the Biomimicry 3.8 staff experts, visit [Synapse.bio](http://Synapse.bio).

# Image Credits

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TECHNOLOGY  
Flickr.com | Rob Bertholf

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CROPS  
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